fectly understand the simplicity of the problem of drawing the shortest line on any given convex surface, such as the surface of this block of wood (shaped to illustrate Newton's dynamical theory of the elliptic motion of a planet round the sun) which you see on the table before you. I solve the problem practically by stretching a thin cord between the two points, and pressing it a little this way or that way with my fingers till I see and feel that it lies along the shortest distance between them. And now, when I tell you that Liouville has reduced to this splendidly simple problem of drawing a shortest line (geodetic line it is called) on any given curved surface every conceivable problem of dynamics involving only two freedoms to move, I am sure you will understand sufficiently to admire the great beauty of this theorem.

The doctrine of isoperimetrical problems in its relation to dynamics is very valuable in helping to theoretical investigation of an exceedingly important subject for astronomy and physics —the stability of motion, regarding which, however, I can only this evening venture to show you some experimental illustrations.

The lecture was concluded with experiments illustrating—

(1) Rigid bodies (teetotums, boys' tops, ovals, oblates, &c.) placed on a horizontal plane, and caused to spin round on a vertical axis, and found to be thus rendered stable or unstable according as the equilibrium without spinning is unstable or stable.

(2) The stability or instability of a simple pendulum whose point of support is caused to vibrate up and down in a vertical line, investigated mathematically by Lord Rayleigh.

(3) The crispations of a liquid supported on a vibrating plate, investigated experimentally by Faraday; and the instability of a liquid in a glass jar, vibrating up and down in a vertical line, demonstrated mathematically by Lord Rayleigh.

(4) The instability of water in a prolate hollow vessel, and its stability in an oblate hollow vessel, each caused to rotate rapidly round its axis of figure,[1] which were announced to Section A of the British Association at its Glasgow meeting in 1876 as results of an investigation not then published, and which has not been published up to the present time.

GEOLOGICAL SURVEY OF THE UNITED KINGDOM.[2]

II.

SCOTLAND.

Lewisian Gneiss.—The most ancient rocks in the British Islands, forming what is known as the Lewisian Gneiss, have now been mapped continuously throughout the whole of their extent on the mainland, from Cape Wrath to the Kyles of Skye. They have been found to occur there in two distinct conditions. Along the western borders of Sutherland and Ross they form an irregular platform on which all later formations rest. The detailed work of the survey has brought to light the fact that this platform had an exceedingly uneven surface before the very oldest of the sedimentary formations were laid down upon it. Mountains of gneiss from 2000 to 3000 feet high, with wide and deep intervening valleys, already existed before the period of the Torridon Sandstone, and were submerged beneath the waters in which that Sandstone was accumulated. But to the east of this primeval topography, owing to the gigantic dislocations which have now been traced for upwards of 100 miles from the northern shores of Sutherland into Skye, large slices of the deeply buried gneiss have been torn off and have been driven westward upon fractured and crushed rocks of much later date. There are thus areas of gneiss which have been moved and have undergone much consequent internal rearrangement, while to the west of these the old platform, still in great part covered with the younger formations, has been left unaffected and reveals the condition of the oldest rocks at the time when the earliest of these over-lying formations was deposited upon them.

The mapping of this region has shown the Lewisian Gneiss to consist of what were probably masses of various deep-seated igneous rocks, which, partly by segregation and intrusion, and partly by subsequent intense mechanical deformation, have in large measure acquired a gneissic structure. An order of sequence has been made out among the more marked types of erupted material, and it has been further ascertained that the structures superinduced by crushing have taken place at successive periods of great disturbance.

Some of the most important observations in the area of the ancient gneiss are those made in the Loch Maree district. Mr. Clough has found there a group of rocks quite unlike the usual types of the Lewisian series. They consist chiefly of fine mica-schist, quartz-schist, graphite-schist, and limestone, and may be altered sedimentary rocks. If such should prove to be their origin they will possess a special interest as being by far the most ancient vestiges of detrital deposits yet detected in this country. The relation of these rocks to the normal types of gneiss around them have not been very satisfactorily determined.

In the course of the examination of the old gneiss where it lies undisturbed below the unmoved Torridon Sandstone, the officers of the Survey have ascertained that it had undergone successive disruptions and much mechanical deformation before the deposition of that Sandstone, that in short it had already acquired all its present structure and had been irregularly and deeply laid bare by denudation. We are still unable to say how far the earliest foliated arrangement of the gneiss may be due to movements such as those of flow-structure within a plutonic magma, in which the component minerals have segregated out. But there can be no doubt that after any such early structure had been established other structures were superinduced upon the gneiss by subterranean movements. Evidence of these disruptions and of their effects has now been accumulated over the whole area of the mainland.

Torridonian.—The striking mass of chocolate-coloured sandstones, which enters so prominently into the scenery of the west of Sutherland and Ross-shire, has now been mapped throughout its extent on the mainland, with the exception of a small area in the west of the latter county which remains to be completed. Like the far more ancient gneiss on which these strata rest with so marked an unconformability, they are met with in two distinct conditions. To the westward, where they have escaped from the great dislocations already referred to, they lie in almost their original undisturbed positions, insomuch that one can hardly at first realise that their relative antiquity can be so great as it demonstrably is. They resemble portions of the Old Red Sandstone with which at first they were identified, and this resemblance extends even into the practical uses that may be made of them. Along many parts of the West of Sutherland and Ross-shire the thick bedded chocolate-coloured freestones would furnish an excellent building stone in practically unlimited quantities.

An important group of shales has been found to occupy a prominent place towards the base of the Torridon Sandstone in Western Ross-shire. This group has now been followed to the sea-coast, and has been found by Mr. Clough to attain a still larger development in the southern part of the island of Skye. They there contain thin bands of impure limestone, and one of their members of much interest, forming only a thin bed, consists largely of grains of magnetite and zircon. A diligent search for fossils has recently been made by Mr. A. Macconochie in this lower shaly group of the Torridon Sandstone, but hitherto with scarcely any success, certain doubtful track-like markings being the only indications of possible organic remains which have been met with.

In mapping the Applecross district, where the Torridon Sandstone rises into an imposing group of mountains, Mr. Horne has encountered some singular volcanic orifices on a sandstone plateau about 1000 feet above the sea. Two small "necks" which rise there through the Torridon rocks, are filled with blocks of the sandstone mingled with occasional bombs of basalt, the whole being set in a dark green and grey paste of similar materials. The fragments of sandstone have been subjected to considerable alteration, for they have a glazed aspect, while their quartz-grains have acquired a milky opalescent or blue tint. There is no indication of the age of these two volcanic vents, but they may with some probability be assigned to the widespread Tertiary series which has left such prominent memorials in the opposite island of Skye.

During the past year in the district between Loch Kishorn and the head of Loch Carron some tracts of Torridon Sandstone have been mapped, where the effects of the great displacements upon the internal structure of the sandstone are well displayed. In that region, by the effect of these stupendous movements, a wide area of Torridon Sandstone and old gneiss has been inverted and pushed bodily westwards so as now to lie upon the Cambrian formations. This inversion is seen on a great scale in the district of Loch Carron, where the Torridon Sandstone, pushed over the quartzites and limestones, dips eastward for several miles until its base passes under the overturned Lewisian gneiss. The actual inverted unconformable junction of the gneiss and sandstone can still be traced in various places, though elsewhere it has been effaced by intense deformation. And not only may the inverted unconformability be recognised, but it can be shown that an overlap of the older parts of the Torridon Sandstone takes place against the uneven surface of the overlying gneiss. Messrs. Peach and Horne, who have mapped this remarkable structure, find that the sandstones have been crushed and have become partially schistose, with a development of mica and other minerals along the planes of movement; also that pegmatitic veins of quartz and felspar have been formed by segregation in rents of the strata.

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[1] NATURE, 1877, vol. xv. p. 297, "On the Precessional Motion of a Liquid."

[2] Annual Report of the Geological Survey for the year ending December, 31, 1892. By Sir Archibald Geikie, F.R.S., Director General. From the Report of the Science and Art Department for 1892. (Some of those portions of the Report which describe the scientific results of the Survey operations during the last few years are reprinted here). (Continued from page 497.)

The same intense subterranean movements have profoundly affected the structure of the overlying masses of old gneiss. As these rocks are followed eastwards for several miles they appear more and more sheared, until at last they are succeeded by siliceous granulitic flagstones, such as have been named by the surveyors "Moine-schists." On the south side of Loch Carron, Mr. Peach has recently obtained evidence which, if confirmed by further research, will have an important bearing on the interpretation of these schists, which have hitherto presented a very difficult problem. He finds that from the nature of the schists and their mode of occurrence in that locality, they appear to be altered Torridon Sandstone, which has been caught and enclosed within a great synclinal fold by the mass of old gneiss as it was driven westward. They consist of material similar to that of the undoubted Torridon Sandstone, where it has been affected by the greater movements, and they show in many places that they have been originally pebbly felspathic grits. To the eastward of this zone of probably clastic material other huge masses of the Lewisian gneiss have been pushed up and more or less deformed.

Eastern or Younger Gneiss.—While the chief part of the working season in the north-west Highlands has been devoted to the prosecution of the critical work in the districts just referred to, some progress has also been made in the mapping of the area of the eastern or younger schists (Moine-schists), which, brought forward by the higher thrust-planes, spread over so large an area of Sutherland and Ross. I have referred above to the extreme difficulty of ascertaining what has been the origin of these schists, and to the suggestive observations of Mr. Peach which may eventually lead to the recognition of these rocks as altered sediments. When the officers of the survey some years ago made a few preliminary traverses across the north of Sutherland, before beginning to map that region in detail, they were disposed to believe that certain belts of coarse, banded, gneisses which appear on the coast, were portions of the old gneiss that had escaped the crushing which produced the peculiar granulitic structure of the so-called Moine-schists. Closer examination and detailed mapping of these rocks have led Mr. Horne to modify this view. He regards it as certain that altered sediments form an integral portion of the granulitic schists and gneiss of that district. But he also finds that these schists and gneisses are traversed by abundant belts and veins of foliated and unfoliated granite, showing no cataclastic structure. From these larger portions of granitic material countless minute folia of the same substance have proceeded along the foliation planes of the schists. Hence three distinct types of gneiss have been produced: (1) granitoid gneiss or gneissose granite; (2) an intermediate type consisting of alternations of granulitic and granitic materials; (3) well-banded biotite-gneiss. If these Kirktomy gneisses really belonged to the Lewisian system, it would follow that the granitic types thus developed must be later than the granulitic schists and gneisses. If, on the other hand, as is most probable, they are of post-Cambrian age, then we must admit that in rocks of this type petrographical characters cannot be regarded as furnishing by themselves a reliable chronological index.

Schists of Central and Southern Highlands.—In the Central and Southern Highlands, accumulating evidence, both in the field and, as already stated, from microscopical research, goes to show that the main mass of the rocks composing that region are a thick and varied series of sedimentary deposits which, together with their associated igneous materials, have undergone extensive metamorphism. The degree of alteration sometimes reaches a point beyond which the original clastic structures are no longer traceable. But even where this is the case with some members of the series, others are found associated with them which can be recognised, and which indicate the persistence of the several stratigraphical groups. An area where there has been hardly any metamorphism has recently been mapped by Mr. J. B. Hill in the district of Loch Awe. The rocks in that tract consist of grits, phyllites and limestones, which in their unaltered condition resemble ordinary Palæozoic sedimentary strata. These have been traced by Mr. Hill continuously into the crystalline schists of the central Highlands.

Much attention has recently been given to the eruptive rocks associated with the schists of the central and southern Highlands. Some of these are dark basic sills, which were injected before the plication and metamorphism of the surrounding rocks, others are later granitic intrusions, probably of different epochs of eruption. That a gradation from basic to acid composition within the same eruptive mass may sometimes be detected, indicating probably the order of consolidation of the component materials of an igneous protrusion, has been well shown by recent work of Messrs. Dakyns and Teall. Mr. Barrow's work in Forfarshire has brought to light the existence of a vast number of comparatively small bosses, veins, or lenticles of a granite, with both white and black mica, and usually showing a more or less distinctly foliated structure. He has also found numerous intrusions of a biotite gneiss. Both these rocks are accompanied by an alteration of the surrounding schists.

Jurassic.—In pursuance of the plan of field-work sketched in previous reports, Mr. H. B. Woodward was stationed in the Isle of Raasay, for the purpose of mapping the various members of the Jurassic series there exposed. He had nearly completed this survey when the short season came to an end, having traced the limits of the Great and Inferior Oolite, the Upper, Middle, and Lower Lias, and the Red Rocks underlying the Lias which are probably of Triassic age. In the course of his work he discovered a hitherto unsuspected bed of Oolitic ironstone in the upper part of the Middle Lias. A thickness of 4 feet 6 inches was seen by him, but the bed may possibly be a little thicker. In geological position this bed corresponds with the well known Cleveland iron-ore and other seams. An analysis, made by Mr. A. Dick, junr., under the superintendence of his father Mr. Allan Dick, who made in 1856 one of the earlier analyses of the Cleveland ore, showed the Raasay stone to contain a little more than 30 per cent. of metallic iron, the proportion in the Cleveland ore ranging from 30 to a little above 33 per cent.

Glacial Deposits.—In Scotland the mapping of the superficial deposits has gone on simultaneously with that of the solid rocks underneath, and in some parts of the country, where these deposits are especially complicated, the progress of the surveying is necessarily somewhat retarded. In the north-west Highlands some singular evidence has been obtained as to the thickness and flow of the great ice-sheet, at what seems to have been the time of maximum glaciation. Not only are the sides of the mountains well ice-worn, but there is evidence that the fragments of the characteristic Moine-schists of the interior of Sutherland and Ross have been carried up westward across the great ridges, thus proving that the axis of movement of the ice did not coincide with the present watershed of the country.

Some interesting relics of the later or valley glaciers have been mapped at Loch Torridon. Mr. Hinxman has traced the moraines down to the latest raised beaches of the west coast, Mr. Peach finds evidence that in the north of Sutherland glaciers continued to shed their moraines in the sea at the time of the formation of the 50-feet Raised Beach. Some of the high-level terraces of the River Naver in that district appear to have been formed between the edge of the ice and the side of the valley at a time when a glacier passed down the bed of the valley. Successive terraces, formed in this way as the glacier shrank backwards, may never have reached across the valley, though similar shelves of gravel may now occur on either side.

IRELAND.

The most important recent work of the staff of the survey of Ireland has been a re-examination of certain portions of the country with the view of determining how far the gneisses and schists represented on the maps could be correlated with those the same species, the widely different results are probably due to the trees furnishing the timber having been grown under different conditions. Mr. Mackenzie mentions a curious fact "observed in the working of the various pine timbers I have named. It was found that the wood of pines having three leaves in a sheath was, as a rule, much harder than those having only two, whilst all those having five leaves in a sheath were uniformly soft, and when dressed had a silky appearance. So general is this characteristic that one could almost at once tell to what class a certain plank of pine timber belonged." These observations we do not remember to have seen previously recorded.

"The Diseases of Conifers." Although in German there is a literature of considerable extent on this subject, the publications in English are few. Prof. Marshall Ward is a very careful and competent observer, and his contribution to the report is of great value both to the man of science and to the practical forester.

Mr. W. F. H. Blandford's insects injurious to conifers is an excellent *résumé* of all that is known up to date of the life-history of the various insect pests, which have been noted as injurious to conifers. How important this subject is may be judged by the destruction wrought by the larvæ of *Liparus monacha* between 1853 and 1868 in East Prussia, Poland, and Russia, where the spruce was killed over an area of 7000 square German miles. A similar instance is that afforded in 1890 in the Bavarian forests by the same destructive insect, the loss caused by this to the revenue being estimated at £40,000. Those, however, who, like the writer of these notes, travelled over the districts affected during the ravages of the larvæ, would realise much more vividly the gravity of the attack than others could from a mere perusal of statistics.

Not the least valuable portions of the report are the statistics of conifers in the British Islands, and the value in the British Islands of introduced conifers, by Mr. Malcolm Dunn. These statistics represent an enormous amount of energy and perseverance on the part of the compiler. The tabulated forms give particulars from a large number of places in the British Islands, and deal with the soil, altitude, age of trees, their height, girth, &c. The list of conifers and largest specimens, also by Mr. Dunn, gives the dimensions of the largest specimens taken from the above-mentioned tables and also the number of returns respecting each species. G. N.

THE EARTHQUAKES IN ZANTE.

LAST week we noted the fact that another disastrous earthquake had occurred in Zante on Monday, April 17, and that it had been followed by various slighter shocks. According to a special correspondent of the *Times* at the town of Zante, the centre of the disturbance seems to have been under the sea about two miles from land. Before the great shock the inhabitants of the district of Vasilikos, near this centre, heard submarine rumblings, which increased in loudness till the earthquake occurred. Two huge boulders were detached from the neighbouring mountain and rolled into the valley beneath. The same correspondent records that on the afternoon of April 21 there were several violent shocks.

The conditions under which this series of earthquakes has occurred will no doubt be carefully studied. Meanwhile we may call attention to a good article contributed to the *Mediterranean Naturalist* for April by Mr. W. G. Forster, seismologist, manager, and electrician, Eastern Telegraph, Zante, on the earthquakes which did so much damage in January. From this paper we reprint the following historic statement:—

"From the traditions of the place it has always been considered pretty certain that Zante must invariably expect a more or less severe earthquake about every thirty years. I find, however, that this cycle of seismic disturbances is common to all earthquake districts in south-eastern Europe and Asia Minor, and that there exists also a fairly proven and established law which governs these periods of visitation, for instance, whenever any long time has elapsed without the slight shocks—which average one or more a week in earthquake districts of non-volcanic regions—and when to these periods of comparative quiescence succeeds one of constant earth tremors, then a disastrous shock is nearly certain to take place. This is a very important point, and cannot be neglected when the question as to the origin of the shocks is under consideration.

"The last strong local earthquake previous to the present series of shocks occurred on October 26, 1873, and although it was far less severe, it originated within a mile or so of the present one's centrum, as proven by a knot of submarine cable having been then lost, buried under the immense mass which fell into it, at the bottom of the sea; and by the measurements taken at the time.

"This earthquake had precisely the same characteristics as the present one, both previously and subsequently to its occurrence, and although very many severe and slight shocks have been felt since 1873, in no case were they of so pronounced a local nature as those just recently experienced. When the great earthquake of August 27, 1886, occurred, which destroyed Filiatra on the mainland to the south-east of Zante, this island was fortunately outside the direct vibrative waves of seismic forces radiating from the centrum of that shock; which covered up six knots of submarine cable in latitude 37°25′, longitude 21°11′ east of Greenwich; but still it did considerable damage, and its force was severe enough to cause the greatest alarm even in so distant a place as Malta.

"From that year until the spring of 1890 there were numbers of small shocks, but after then and up to August, 1892, only a very few tremors were recorded. On August 16 last year about twelve small shocks suddenly occurred during the day, purely local, and all from east to west. After three days of absolute tranquillity they began again, and although merely pulsations they were of a very pronounced character.

"At midnight on August 27 the shock was strong, and from then until the still smarter shocks of September 3 and 5 the earth seemed always shaking. Another few days of quiescence were followed by a renewal of shocks. This state of things continued until the middle of January last—and was again succeeded by a fortnight of perfect tranquillity. At 9 p.m. on January 30 a very distinct rumbling occurred, which was followed by a short, sharp shock, as if from some falling mass, and then all was still again. I noticed after the shock a series of small ripples on the sea, which was previously and subsequently quite calm. The night passed very quietly until 5.34 a.m., local time, when the whole island began to sway terrifically from east to west, with a purely undulating motion, finishing up by a movement which I can only describe as being similar to that of some mighty force wrenching out the bowels of the earth. This shock lasted twelve seconds, and its centre was undoubtedly in the sea very close to the town, and due east of the same. From its apex of origin its range of destruction, on the frontage of the town, was not wider than two miles, spreading out to about fifteen when it reached the villages at the base of the range of hills, six miles off.

"The destructive force had a tendency to incline from due east to the north-west of the island, which is about 27 miles in length by an average breadth of eight, a subsequent shock taking a much lower range. During the whole day shocks were alarmingly frequent and numbered some hundreds between the first and nightfall when everybody went to the open ground in a most panicstricken condition. At 1.56 a.m. on February 1 another terrific shock took place—not so severe as the first, but with a range towards the south-west and of increasing destructive force. This shock lasted 20 seconds and was also succeeded by numberless others. After 23 hours a third severe shock occurred and periodically during the whole week others of decreasing intensity took place. Since the first shock until the present date, at least one thousand (including pulsations and tremors) have been felt.

"Of course the direct and indirect damage has been very great owing to the extensive zone of destruction, the scattered nature of the villages and to the bad construction of the houses in general and to their dilapidated condition owing to extreme poverty of the island. At least half a million sterling is required to rebuild the place, and as this amount can never be realised many of the ruins are likely to remain untouched and most of the population will have to emigrate."

SCIENTIFIC SERIALS.

American Journal of Mathematics, vol. xv. 1 (Baltimore: Johns Hopkins Press, January, 1893).—The pièce de résistance of this number is a memoir by Prof. Cayley on symmetric functions and seminvariants (pp. 1–74), in which the author further develops the theory of seminvariants, and in connection therewith is led to some investigations on symmetric functions. The subject is treated with characteristic ability and affords ample evidence of the writer's recovery from his recent serious